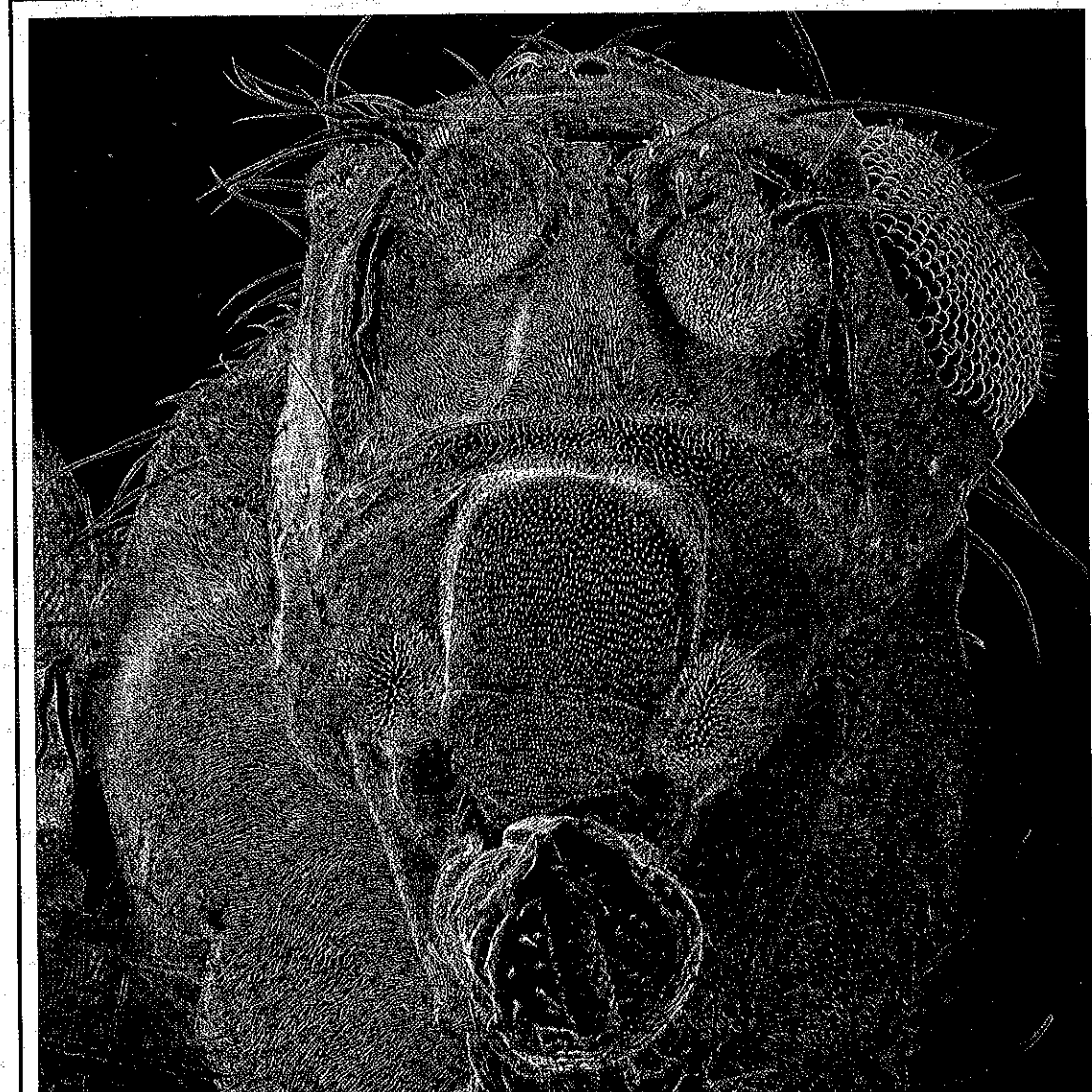
CHAPTER 11

GENE EXPRESSION



This fruit fly has only one eye due to a mutation in a gene that regulates development.

FOCUS CONCEPT: *Cell Structure and Function*

As you read this chapter, note how gene structure enables prokaryotic and eukaryotic cells to control how and when proteins are produced.

BIOLOGY INTERACTIVE TUTOR Unit 6—*Gene Expression* Topics 1–6

CONTROL OF GENE EXPRESSION

SECTION 11-1

OBJECTIVES

▲ Define the term *gene expression.*

● Describe the regulation of the *lac* operon in prokaryotes.

■ Distinguish between introns and exons.

◆ Describe the role of enhancers in the control of gene expression.

Cells use information in genes to build hundreds of different proteins, each with a unique function. But not all proteins are required by the cell at any one time. By regulating gene expression, cells are able to control when each protein is made.

ROLE OF GENE EXPRESSION

Gene expression is the activation of a gene that results in the formation of a protein. A gene is said to be "expressed," or turned "on," when transcription occurs. But cells do not always need to produce all of the proteins for which their genes contain instructions. Recall from Chapter 3 that proteins have many different functions. Some proteins play a structural role. Others are enzymes that act as catalysts in chemical reactions. Mechanisms to control gene expression have evolved to ensure that each protein is produced only when it is needed.

The complete genetic material contained in an individual is called the **genome** (JEE-nohm). By regulating gene expression, cells are able to control which portion of the genome will be expressed and when. Gene expression occurs in two steps, transcription and translation. Gene expression begins when the enzyme RNA polymerase transcribes the DNA nucleotide sequence of a gene into a specific mRNA. During translation, this mRNA then migrates to a ribosome, where it is translated into a specific protein.

Word Roots and Origins

genome

from the words *gene* and *chromosome*

GENE EXPRESSION IN PROKARYOTES

Scientists first studied gene expression in prokaryotes. Much of our initial knowledge of gene expression comes from the work of French scientists Francois Jacob (1920–) and Jacques Monod (1910–1976). Jacob and Monod discovered how genes control the metabolism of the sugar lactose in *Escherichia coli,* a bacterium that lives in the human intestine.

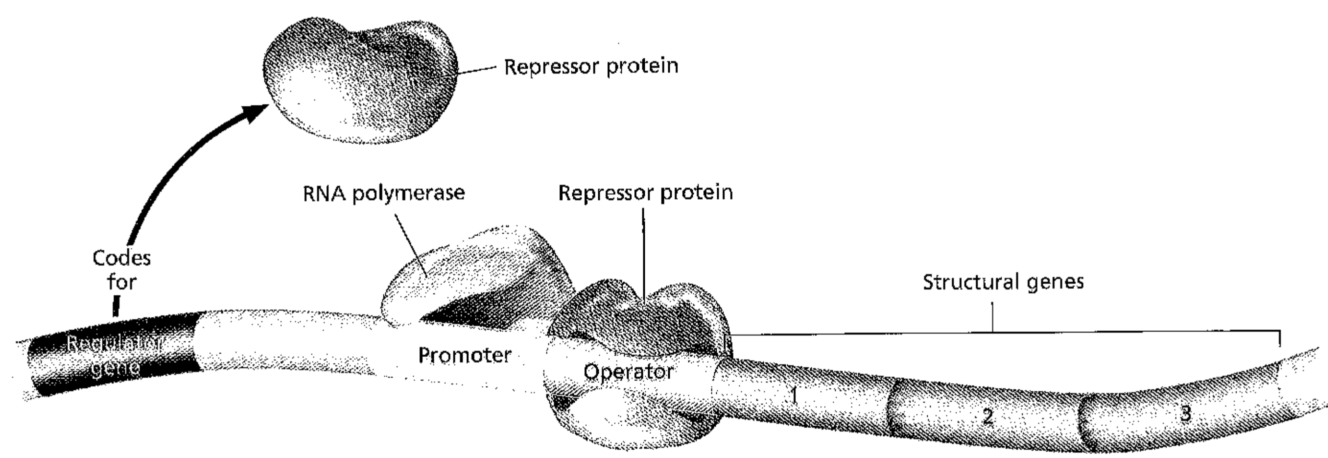


FIGURE 11-1
In the *lac* operon of *E. coli*, three structural genes code for the enzymes needed to utilize lactose. When lactose is absent, a repressor protein attaches to the operator. The presence of the repressor protein prevents RNA polymerase from binding to the structural genes, blocking transcription.

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Found naturally in cow's milk, lactose is a disaccharide that is composed of the monosaccharides glucose and galactose. When you drink cow's milk, the presence of lactose stimulates *E. coli* to produce three enzymes. These three enzymes control metabolism of lactose and are adjacent on the chromosome. The production of these enzymes is controlled by three regulatory elements found within the DNA of *E. coli*. These three regulatory elements are as follows:

- **Structural genes** Genes that code for particular polypeptides are called ***structural genes.*** The structural genes studied by Jacob and Monod coded for the enzymes that allow *E. coli* to break down and utilize lactose.
- **Promoter** As you learned in Chapter 10, a promoter is a DNA segment that recognizes the enzyme RNA polymerase and thus promotes transcription.
- **Operator** An **operator** is a DNA segment that serves as a binding site for an inhibitory protein that blocks transcription and prevents protein synthesis from occurring.

The structural genes, the promoter, and the operator collectively form an operon. An **operon** (AHP-uhr-AHN) is a series of genes that code for specific products and the regulatory elements that control these genes. Researchers have found that the clustered arrangement of genes that forms an operon is a pattern that occurs commonly among bacteria. Jacob and Monod named the operon they studied the ***lac* operon** because its structural genes coded for the enzymes that regulate lactose metabolism. The *lac* operon includes the entire segment of DNA required to produce the enzymes involved in lactose metabolism.

In their work with the *lac* operon, Jacob and Monod found that the genes for the enzymes for lactose utilization were expressed *only* when lactose was present. How were the bacteria able to shut off these genes when lactose was absent? Their research showed that gene expression in the *lac* operon exhibits two forms: repression and activation.

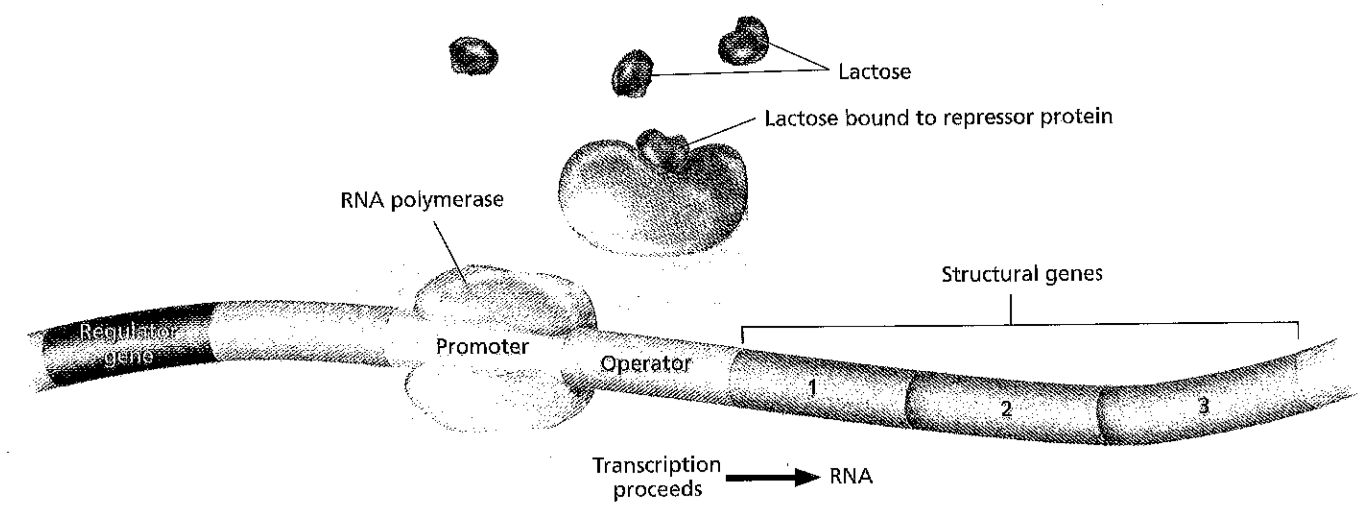

FIGURE 11-2
When lactose is present, it acts as an inducer by binding to the repressor protein and removing it. The removal of the repressor protein allows the transcription of the three structural genes to proceed, producing mRNA.

Repression

In the absence of lactose, a protein called a repressor attaches to the operator. A **repressor protein** is a protein that inhibits a specific gene from being expressed. The attachment of the repressor protein to the operator prohibits RNA polymerase from binding to the structural genes and thus stops transcription from occurring. The blockage of transcription by the action of a repressor protein is called **repression.** Transcription of the structural genes is ultimately controlled by a **regulator gene,** which codes for the production of the repressor protein. The events of repression are summarized in Figure 11-1.

Activation

When lactose is present in the *E. coli* cell, it temporarily binds to the repressor protein on the operator and removes it. The removal of the repressor protein allows RNA polymerase to transcribe the structural genes of the *lac* operon. Since all three structural genes are turned on, all three enzymes required for lactose metabolism are produced. Because it activates, or induces, transcription, lactose acts as an inducer. An **inducer** is a molecule that initiates gene expression. The initiation of transcription by the removal of a repressor protein is called **activation.** Figure 11-2 shows the events that take place when lactose is present in the *E. coli* cell.

The *lac* operon illustrates in simple terms the great advantage of regulating gene expression. Cells of *E. coli* are able to shift between repression and activation, depending on whether lactose is present. Because lactose acts as an inducer, the *lac* operon is transcribed only in the presence of lactose. As a result, lactose induces its own metabolism. When the level of lactose drops, the repressor protein again binds to the operator, shutting off the *lac* operon. The three enzymes used in lactose metabolism are therefore not produced when lactose is not present. By controlling gene expression, *E. coli* conserves resources and produces only those proteins that are needed.